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THE EFFECT OF AN EYE MOVEMENT RECORDER ON HEAD  
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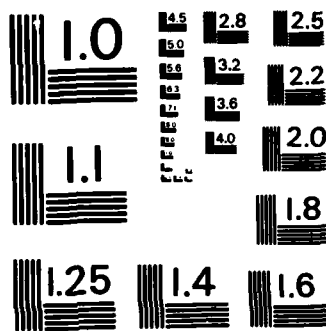
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DCIEM Report 82-R-25

THE EFFECT OF AN EYE MOVEMENT  
RECORDER ON HEAD MOVEMENTS

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## INTRODUCTION

Techniques that enable eye movements to be recorded have made a contribution to the knowledge of human behaviour. Results of eye movement research have been applied in several areas, including the assessment of cognitive workload, the development of road safety programs, the development of consumer marketing strategies and the evaluation of equipment design and effectiveness. Several techniques have been used to record human eye movements including direct ocular observations; electro-oculography (EOG); various contact lens techniques; and reflections from various eye surfaces. A current use of the corneal reflection technique at DCIEM involves recording helicopter pilots' eye movements as they land on the flight deck of HMCS destroyers, in an attempt to determine the effectiveness of visual landing aids.

Although the corneal reflection technique is older and less accurate than other methods, recent advances coupled with the disadvantages of other techniques have made it very useful in several research settings. For example, the NAC Eye Mark Recorder system (an eye movement recorder that utilizes the corneal reflection technique) has been used extensively by the US Army in evaluating the visual performance and workload of helicopter pilots. (2,3,4). These studies reported that the NAC system could be used with a large number of subjects and that normal eye movement patterns were not altered by the use of this equipment (2,4); however, no mention has been made of the extent to which the NAC system alters normal head movement patterns. It has been shown that head movements occur when new visual targets exceed 10 to 15 degrees of visual arc from the initial target in subjects with an unobstructed view (6). It is also known that other types of masks interfere with normal visual search patterns and cause increased head movements (7). Therefore, it is possible that the NAC system could cause abnormal head movements. This, coupled with the added weight of the head mounted NAC apparatus, could lead to excessive fatigue and physical workload for the pilots. This could prove to be detrimental to flying performance and the validity of upcoming studies.

The present study had two major objectives:

- 1) to determine whether the NAC Eye Mark system alters the normal pattern of subject head movement in a typical simulated helicopter piloting tasks; and
- 2) to obtain subjective evaluations from subjects while wearing the NAC eye mask concerning field of view, acuity, comfort and safety.

## METHOD

Three subjects flew standardized flight profiles with two different mask configurations and, in a no mask condition. The profiles were flown in a CH-124 Sea King simulator with motion in 3 degrees. A measure of total linear head movement in the X-Y plane was measured and analyzed to determine the effects of

the different masks on head movements.

## APPARATUS

The basic NAC Eye Mark system consists of a hard plastic mask which fits over the subject's nose, eyes and forehead with a wide angle lens located on the centreline of the face, slightly above the eyes. A silvered mirror located in front of the subjects eyes is used to obtain the point of fixation when eye movements are being recorded. Although eye movements were not recorded in this study, the apparatus was used exactly as if eye movements were being recorded. The masks were attached to the standard CF aircrew helmet by three adjustable straps.

Two variations of the NAC mask were tested. The Mark I mask was unmodified and consisted of a full silvered mirror on the right eyepiece and a transparent left eyepiece. The Mark II had the lower horizontal section of the mask removed and the eye pieces consisted of semi silvered mirrors for both eyes. The Mark II mask was tested to determine if reduced weight, increased peripheral vision and binocular vision would result in different user performance.

A video camera was mounted on the glare shield of the instrument panel and recorded torso and head movements of the subjects. The image was recorded on a video cassette recorder and analysed on a HP 9874 digitizer driven by a HP 9845B desktop computer.

## PROCEDURES

Three subjects, all fully qualified CF Sea King pilots, participated in the study. Each subject was required to fly three identical, twenty minute flight profiles, one for each of the three mask configurations (Mark I, Mark II, helmet only). The flight profiles consisted of a series of simulated sono buoy dips and a simulated TACAN approach. Each experimental trial consisted of an initial ten minute familiarization phase followed by a ten minute recording phase. The subjects were not told when the recording phase began. During the recording phase, the video camera recorded all subjects' head and torso movements. The order of wearing the three masks configurations was balanced across subjects.

To determine if head movement was altered by the wearing of the masks, total linear movement of a helmet mounted reference point in the X-Y plane was measured for the initial five minutes of the recording phase using the digitizing tablet. Total linear movements were then subjected to a one factor, repeated measures analysis of variance.

Throughout the trials, all comments by the subjects were recorded. After each trial the subjects discussed mask comfort, visual acuity, visual angles, safety, slippage and overall

performance with the investigators.

Two researchers independently measured the linear movement of each subject in each condition to provide a check on the reliability of the measurement technique. These measures were compared using a paired T-test.

### RESULTS

The differences between the independent measures were found to be nonsignificant and it was concluded that the measurement technique was reliable.

Since the analysis of variance showed that there was a significant variance between mask conditions, the results were subjected to a Newman-Keuls multiple comparison test. This revealed that significantly more head movements were made with the Mark I mask (unmodified) than the no mask condition, and there was no significant difference between the Mark II mask (modified) and the no mask condition. Appendix 1 contains a summary of these results.

Table 1 summarizes the subjective responses of the pilots and illustrates that the Mark I mask was preferred by the subjects for several reasons.

Table 1: Subjective Responses

#### Mark I Positive Responses

good comfort  
not restrictive to head movement  
not fatiguing  
good fit  
no sight hinderance  
no slippage

#### Mark I Negative Responses

hint of vertigo

#### Mark II Positive Responses

good comfort  
good fit  
not restrictive to head movement  
no slippage

#### Mark II Negative Responses

induces vertigo  
hard to read instruments  
alters normal eye patterns  
fatiguing to the eyes

### DISCUSSION

The increase in head movement observed in the Mark I condition can be attributed to two factors. First, since the mask allowed very limited peripheral vision, the subject was forced to move his head in order to bring an object into his field of view. In effect, with the Mark I mask, the subjects were presented with an expanded form of tunnel vision and were forced to rotate or elevate their head to see an object outside their



existing field of view.

The second factor was the eyepiece used on the Mark I mask. Since the right side of the eyepiece was a full mirror, the subject had only monocular vision with his left eye. This situation may have led to the subjects adopting some abnormal head positions in an effort to increase their visual performance. The problem was further compounded by the relatively low light levels that were present in the helicopter simulator.

It seems that the Mark II mask did not cause increased head movements because the condition allowed complete peripheral vision allowing the subjects to maintain their normal visual patterns without having to rotate or elevate their head. The binocular vision also allowed subjects to maintain their normal head movement patterns without assuming atypical postures.

The subjects' comments indicated that the Mark I mask was preferred to the Mark II mask in spite of the observed increase in head movements. This choice was primarily due to the fact that the Mark II mask had semi-silvered eyepieces over both eyes. This condition was very similar to wearing a pair of sunglasses. Because of the reduced lighting level in the simulator, the added effect of the "sunglasses" made the instrument panel difficult to read, and as reported by the subjects, created abnormal eye patterns. These abnormal patterns resulted from the excessive time required to read the instruments, thereby forcing the subjects to neglect other instruments. It may be this condition that led two subjects to report eye fatigue. However, subsequent work with the two masks has shown that in actual flight where the ambient light levels are higher, the Mark II mask is preferred since it allows almost complete peripheral vision and the semi silvered mirrors do not lead to eye fatigue.

A final point of discussion pertains to the simulator itself. The simulator used in this study was an Instrument Flight Rules (IFR) trainer and as such, did not have any external visual reference points. This feature limited the study to IFR flight and therefore the results may be relevant only to this type of flight. Further, the low light levels in the simulator combined with the eyepieces used may have created conditions which are not representative of actual flight.

#### CONCLUSIONS

Concerning the analysis technique, it was shown that the measurement of total linear movement of the subjects head could be reliably accomplished with the equipment and method used.

The unmodified NAC eye mark recording system with a full silvered mirror on the right eyepiece was found to cause significantly more head movement in IFR flight than a no mask condition. It was also demonstrated that an NAC mask with the lower horizontal section removed and semi-silvered lenses on both eyes

did not differ significantly from the no mask condition in terms of head movements; in contrast, the unmodified Mark I mask was the preferred choice of the subjects since the eye pieces did not cause eye fatigue with the lighting conditions in the simulator. Subsequent work has shown that in actual flight conditions, the Mark II mask was preferred, since the increased light levels of actual flight alleviated the problem of eye fatigue.

After several flights in an actual aircraft, it was decided that the Mark II mask would be more appropriate for upcoming DCIEM studies due to the increased peripheral vision and binocular vision it provides.

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Appendix 1

Raw Data

Condition

Subject	No mask	MarkII	MarkI
1	2195	5914	4655
2	2031	3680	3144
3	3042	4862	3928

Summary Table for Analysis of Variance

Source	Sum of Squares	df	Mean Square	F ratio	significance
Masks (A)	8777496	2	4388748	12.106	<.05
Subject (B)	2779049	2	1389524	3.833	NS
A x B	1450057	4	362514		

Newman-Keuls Analysis

Q value for the no mask and Mark I conditions = 4.943

Q value for the no mask and the Mark II conditions = 3.065

Q critical at .05 = 4.34